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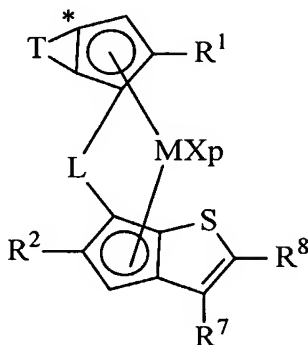
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(54) Title: PROCESS FOR POLYMERIZING 1-HEXENE OR HIGHER ALPHA-OLEFINS



(I)

(57) Abstract: A process for preparing a polymer containing derived units of one or more alpha olefins of formula  $\text{CH}_2=\text{CHW}$  wherein W is a  $\text{C}_3\text{-C}_{10}$  hydrocarbon radical and optionally from 0 to 81 % by mol of derived units of propylene or 1-butene, comprising contacting under polymerization conditions one or more alpha olefins of formula  $\text{CH}_2=\text{CHW}$  and optionally propylene or 1-butene in the presence of a catalyst system obtainable by contacting: a) a metallocene compound of formula (I) wherein M, X, L, T,  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^7$  and  $\text{R}^8$  are described in the text; and (b) an alumoxane or a compound capable of forming an alkyl metallocene cation.

**Process for polymerizing 1-hexene or higher alpha-olefins**

The present invention relates to a process for obtaining a polymer comprising 1-hexene or higher alpha-olefins derived units, by using a specific class of metallocene compounds, that allows to obtain polymers having high molecular weight in high yields.

Metallocene compounds are well known catalyst components for the polymerization of alpha-olefins. However they are mainly used for the (co)polymerization of ethylene, propylene and 1-butene. Polymerization of 1-hexene and higher alpha olefins by using metallocene catalyst components is discussed in some papers. For example US 6,566,544 discloses in table 10 the polymerization of 1-hexene by using  $\text{Ind}_2\text{ZrMe}_2$  and bis(2-phenylindenyl)zirconium dimethyl. The molecular weight of the obtained polymers are quite low. in *Macromol. Chem.Phys.* 200, 1208-1219 (1999), 1-hexene is polymerized in the presence of  $\text{iPr}(\text{CpFlu})\text{ZrCl}_2$ . The polymer obtained has a syndiotactic structure and the molecular mass of the polymer obtained is close to  $20000 \text{ g mol}^{-1}$ . In *Journal of Polymer Science: Part A: Polymer Chemistry*, Vol 37, 283-292 (1999) a series of metallocene compounds have been tested in 1-hexene polymerization. *Rac*- $[\text{Me}_2\text{Ge}(\eta^5\text{-C}_5\text{H}_2,3,5\text{-Me}_3)\text{MCl}_2$  (M = Zr or Hf) allows to obtain 1-hexene polymers having a very high molecular weight. However the synthesis of these compounds can be difficult and the polymerization activity can be increased.

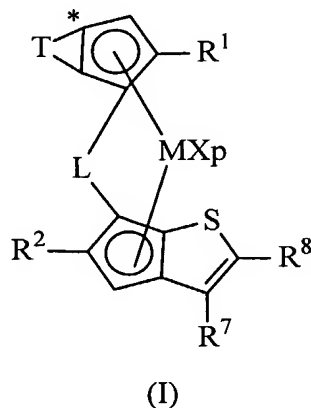
WO 01/46278 relates to a polymerization process for producing a copolymer containing from 60 to 94% mol of alpha olefins having from 3 to 6 carbon atoms, and from 6 to 40% mol of alpha olefins having at least one carbon atom more than the first one. In the examples propylene is copolymerized with 1-hexene. These copolymers are obtained with a metallocene compound different from that one used in the present invention, moreover the molecular weight of the obtained copolymers can still be improved. Finally the present invention is directed to a copolymer that contains a smaller amount of propylene or 1-butene.

Thus there is still the need to find a class of metallocene compounds able to give 1-hexene or higher alpha-olefins (co)polymers having an high molecular weight in high yields.

An object of the present invention is a process for preparing a polymer containing derived units of one or more alpha olefins of formula  $\text{CH}_2=\text{CHW}$  wherein W is a  $\text{C}_3\text{-C}_{10}$  hydrocarbon radical and optionally from 0 to 81% by mol; preferably from 0 to 70% by mol, more preferably from 0 to 59% by mol, of derived units of propylene or 1-butene, comprising contacting under polymerization conditions one or more alpha olefins of

formula  $\text{CH}_2=\text{CHW}$  and optionally propylene or 1-butene in the presence of a catalyst system obtainable by contacting:

a) a metallocene compound of formula (I) in the rac or racemic-like form



wherein

M is an atom of a transition metal selected from those belonging to group 3, 4, 5, 6 or to the lanthanide or actinide groups in the Periodic Table of the Elements; preferably M is titanium, zirconium or hafnium;

p is an integer from 0 to 3, preferably p is 2, being equal to the formal oxidation state of the metal M minus 2;

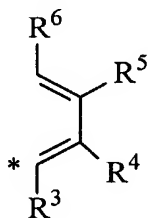
X, same or different, is a hydrogen atom, a halogen atom, or a R, OR,  $\text{OSO}_2\text{CF}_3$ ,  $\text{OCOR}$ , SR,  $\text{NR}_2$  or  $\text{PR}_2$  group, wherein R is a are linear or branched, cyclic or acyclic,  $\text{C}_1\text{-C}_{40}$ -alkyl,  $\text{C}_2\text{-C}_{40}$  alkenyl,  $\text{C}_2\text{-C}_{40}$  alkynyl,  $\text{C}_6\text{-C}_{40}$ -aryl,  $\text{C}_7\text{-C}_{40}$ -alkylaryl or  $\text{C}_7\text{-C}_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R is a linear or branched  $\text{C}_1\text{-C}_{20}$ -alkyl radical; or two X can optionally form a substituted or unsubstituted butadienyl radical or a  $\text{OR}'\text{O}$  group wherein R' is a divalent radical selected from  $\text{C}_1\text{-C}_{40}$  alkylidene,  $\text{C}_6\text{-C}_{40}$  arylidene,  $\text{C}_7\text{-C}_{40}$  alkylarylidene and  $\text{C}_7\text{-C}_{40}$  arylalkylidene radicals; preferably X is a hydrogen atom, a halogen atom or a R group; more preferably X is chlorine or a  $\text{C}_1\text{-C}_{10}$ -alkyl radical; such as methyl, or ethyl radicals;

L is a divalent  $\text{C}_1\text{-C}_{40}$  hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements or a divalent silylene radical containing up to 5 silicon atom; preferably L is a divalent bridging group selected from  $\text{C}_1\text{-C}_{40}$  alkylidene,  $\text{C}_3\text{-C}_{40}$  cycloalkylidene,  $\text{C}_6\text{-C}_{40}$  arylidene,  $\text{C}_7\text{-C}_{40}$  alkylarylidene, or  $\text{C}_7\text{-C}_{40}$  arylalkylidene radicals optionally containing heteroatoms belonging to groups

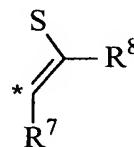
13-17 of the Periodic Table of the Elements, and silylene radical containing up to 5 silicon atoms such as  $\text{SiMe}_2$ ,  $\text{SiPh}_2$ ; preferably L is a group  $(\text{Z}(\text{R}'')_2)_n$  wherein Z is a carbon or a silicon atom, n is 1 or 2 and  $\text{R}''$  is a  $\text{C}_1$ - $\text{C}_{20}$  hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $\text{R}''$  is a linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{20}$ -alkyl,  $\text{C}_2$ - $\text{C}_{20}$  alkenyl,  $\text{C}_2$ - $\text{C}_{20}$  alkynyl,  $\text{C}_6$ - $\text{C}_{20}$ -aryl,  $\text{C}_7$ - $\text{C}_{20}$ -alkylaryl or  $\text{C}_7$ - $\text{C}_{20}$ -arylalkyl radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably the group  $(\text{Z}(\text{R}'')_2)_n$  is  $\text{Si}(\text{CH}_3)_2$ ,  $\text{SiPh}_2$ ,  $\text{SiPhMe}$ ,  $\text{SiMe}(\text{SiMe}_3)$ ,  $\text{CH}_2$ ,  $(\text{CH}_2)_2$ , and  $\text{C}(\text{CH}_3)_2$ ;

$\text{R}^1$  and  $\text{R}^2$ , equal to or different from each other, are  $\text{C}_1$ - $\text{C}_{40}$  hydrocarbon radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably they are linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{40}$ -alkyl,  $\text{C}_2$ - $\text{C}_{40}$  alkenyl,  $\text{C}_2$ - $\text{C}_{40}$  alkynyl,  $\text{C}_6$ - $\text{C}_{40}$ -aryl,  $\text{C}_7$ - $\text{C}_{40}$ -alkylaryl or  $\text{C}_7$ - $\text{C}_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $\text{R}^1$  and  $\text{R}^2$  are linear or branched,  $\text{C}_1$ - $\text{C}_{20}$ -alkyl radicals; more preferably  $\text{R}^1$  and  $\text{R}^2$  are methyl or ethyl radicals;

T, equal to or different from each other, is a moiety of formula (IIa) or (IIb):



(IIa)



(IIb)

wherein the atom marked with the symbol \* bonds the atom marked with the same symbol in the compound of formula (I);

$\text{R}^3$  is a hydrogen atom or a  $\text{C}_1$ - $\text{C}_{40}$  hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $\text{R}^3$  is a linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{40}$ -alkyl,  $\text{C}_2$ - $\text{C}_{40}$  alkenyl,  $\text{C}_2$ - $\text{C}_{40}$  alkynyl,  $\text{C}_6$ - $\text{C}_{40}$ -aryl,  $\text{C}_7$ - $\text{C}_{40}$ -arylalkyl or a  $\text{C}_7$ - $\text{C}_{40}$ -alkylaryl radical; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $\text{R}^3$  is a linear or branched,  $\text{C}_1$ - $\text{C}_{20}$ -alkyl  $\text{C}_6$ - $\text{C}_{40}$ -aryl,  $\text{C}_7$ - $\text{C}_{40}$ -arylalkyl radical; even more preferably  $\text{R}^3$  is a  $\text{C}_6$ - $\text{C}_{20}$ -aryl radical optionally substituted with one or more  $\text{C}_1$ - $\text{C}_{10}$  alkyl groups;

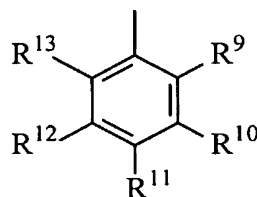
$R^4$  and  $R^6$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$  hydrocarbon radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^4$  and  $R^6$ , equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^4$  and  $R^6$  are hydrogen atoms;

$R^5$  is a hydrogen atom or a  $C_1$ - $C_{40}$  hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^5$  is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $R^5$  is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl radical; even more preferably  $R^5$  is a methyl or ethyl radical;

$R^7$  and  $R^8$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$  hydrocarbon radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $R^7$  and  $R^8$  can optionally form a saturated or unsaturated, 5 or 6 membered rings, said ring can bear  $C_1$ - $C_{20}$  alkyl radicals as substituents; preferably  $R^7$  and  $R^8$  are hydrogen atoms or linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

preferably  $R^8$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl radical; more preferably  $R^8$  is a methyl or ethyl radical;

preferably  $R^7$  is a  $C_1$ - $C_{40}$ -alkyl,  $C_6$ - $C_{40}$ -aryl or a  $C_7$ - $C_{40}$ -arylalkyl; more preferably  $R^7$  is a group of formula (III)



(III)

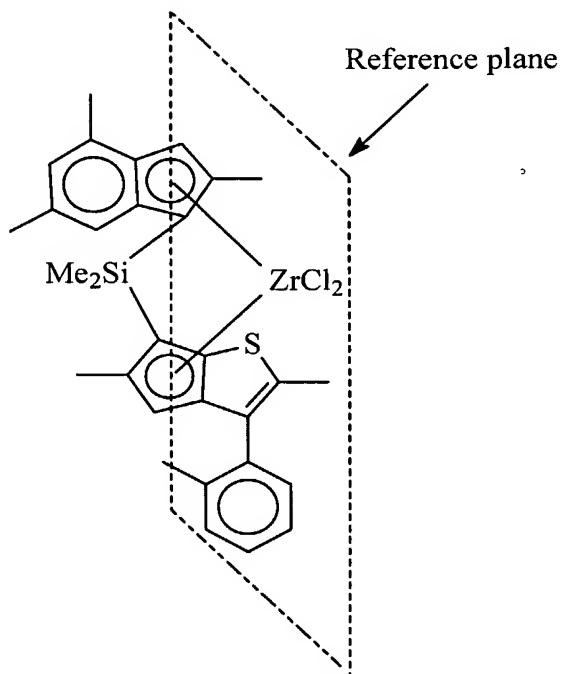
wherein  $R^9$ ,  $R^{10}$ ,  $R^{11}$ ,  $R^{12}$  and  $R^{13}$ , equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic,  $C_1$ - $C_{20}$ -alkyl,  $C_2$ - $C_{20}$  alkenyl,  $C_2$ - $C_{20}$

alkynyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R<sup>9</sup>, and R<sup>12</sup> are a hydrogen atoms; R<sup>10</sup>, R<sup>11</sup> and R<sup>13</sup> are preferably hydrogen atoms or linear or branched, cyclic or acyclic, C<sub>1</sub>-C<sub>10</sub>-alkyl radicals; more preferably R<sup>13</sup> and R<sup>10</sup> are linear or branched, cyclic or acyclic, C<sub>1</sub>-C<sub>10</sub>-alkyl radicals such as methyl or ethyl radicals and R<sup>9</sup>, R<sup>11</sup>, and R<sup>12</sup> are hydrogen atoms;

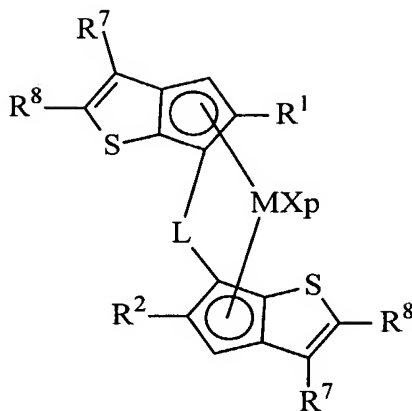
- b) an alumoxane or a compound capable of forming an alkyl metallocene cation; and optionally
- c) an organo aluminum compound.

Metallocene compounds of formula (I) are well known in the art, they can be prepared according to known procedure, such as those described in WO 01/44318, WO 03/045964, PCT/EP02/13552 and DE 10324541.3.

For the purpose of the present invention the term “racemic form” means that the same substituents on the two cyclopentadienyl moieties are on the opposite side with respect to the plane containing the zirconium and the centre of the said cyclopentadienyl moieties. “racemic-like form” means that the bulkier substituents of the two cyclopentadienyl moieties on the metallocene compound are on the opposite side with respect to the plane containing the zirconium and the centre of the said cyclopentadienyl moieties as shown in the following compound:



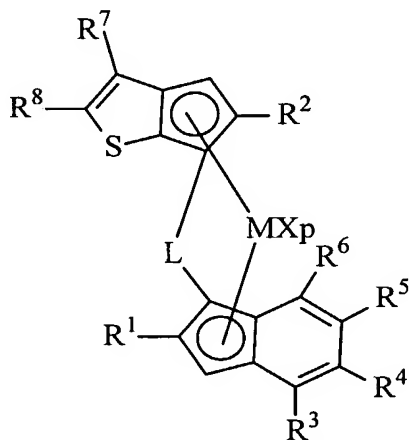
In one embodiment the compound of formula (I) has the following formula (IV)



(IV)

wherein M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>7</sup> and R<sup>8</sup> have the above described meaning.

In an alternative embodiment the compound of formula (I) has the following formula (V)



(V)

wherein

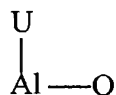
M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup> and R<sup>8</sup> have the above described meaning.

Alumoxanes used as component b) can be obtained by reacting water with an organo-aluminium compound of formula H<sub>j</sub>AlU<sub>3-j</sub> or H<sub>j</sub>Al<sub>2</sub>U<sub>6-j</sub>, where the U substituents, same or different, are hydrogen atoms, halogen atoms, C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cyclalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radicals, optionally containing silicon or germanium atoms, with the proviso that at least one U is different from halogen, and j ranges from 0 to 1, being also a non-integer number. In this reaction the molar ratio of Al/water is preferably comprised between 1:1 and 100:1.

Alumoxanes used as component b) can be obtained by reacting water with an organo-aluminium compound of formula H<sub>j</sub>AlU<sub>3-j</sub> or H<sub>j</sub>Al<sub>2</sub>U<sub>6-j</sub>, where the U substituents, same or different, are hydrogen atoms, halogen atoms, C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cyclalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-

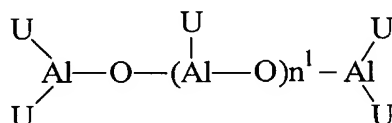
C<sub>20</sub>-alkylaryl or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radicals, optionally containing silicon or germanium atoms, with the proviso that at least one U is different from halogen, and j ranges from 0 to 1, being also a non-integer number. In this reaction the molar ratio of Al/water is preferably comprised between 1:1 and 100:1.

The alumoxanes used in the process according to the invention are considered to be linear, branched or cyclic compounds containing at least one group of the type:

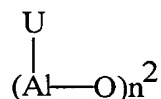


wherein the substituents U, same or different, are defined above.

In particular, alumoxanes of the formula:



can be used in the case of linear compounds, wherein n<sup>1</sup> is 0 or an integer of from 1 to 40 and the substituents U are defined as above; or alumoxanes of the formula:



can be used in the case of cyclic compounds, wherein n<sup>2</sup> is an integer from 2 to 40 and the U substituents are defined as above.

Examples of alumoxanes suitable for use according to the present invention are methylalumoxane (MAO), tetra-(isobutyl)alumoxane (TIBAO), tetra-(2,4,4-trimethylpentyl)alumoxane (TIOAO), tetra-(2,3-dimethylbutyl)alumoxane (TDMBAO) and tetra-(2,3,3-trimethylbutyl)alumoxane (TTMBAO).

Particularly interesting cocatalysts are those described in WO 99/21899 and in WO01/21674 in which the alkyl and aryl groups have specific branched patterns.

Non-limiting examples of aluminium compounds that can be reacted with water to give suitable alumoxanes (b), described in WO 99/21899 and WO01/21674, are:

tris(2,3,3-trimethyl-butyl)aluminium,	tris(2,3-dimethyl-hexyl)aluminium,	tris(2,3-dimethyl-butyl)aluminium,	tris(2,3-dimethyl-pentyl)aluminium,	tris(2,3-dimethyl-heptyl)aluminium,
tris(2-methyl-3-ethyl-pentyl)aluminium,	tris(2-methyl-3-ethyl-hexyl)aluminium,			
tris(2-methyl-3-ethyl-heptyl)aluminium,	tris(2-methyl-3-propyl-hexyl)aluminium,			
tris(2-ethyl-3-methyl-butyl)aluminium,	tris(2-ethyl-3-methyl-pentyl)aluminium,			



tris(2,3-diethyl-pentyl)aluminium, tris(2-propyl-3-methyl-butyl)aluminium, tris(2-isopropyl-3-methyl-butyl)aluminium, tris(2-isobutyl-3-methyl-pentyl)aluminium, tris(2,3,3-trimethyl-pentyl)aluminium, tris(2,3,3-trimethyl-hexyl)aluminium, tris(2-ethyl-3,3-dimethyl-butyl)aluminium, tris(2-ethyl-3,3-dimethyl-pentyl)aluminium, tris(2-isopropyl-3,3-dimethyl-butyl)aluminium, tris(2-trimethylsilyl-propyl)aluminium, tris(2-methyl-3-phenyl-butyl)aluminium, tris(2-ethyl-3-phenyl-butyl)aluminium, tris(2,3-dimethyl-3-phenyl-butyl)aluminium, tris(2-phenyl-propyl)aluminium, tris[2-(4-fluoro-phenyl)-propyl]aluminium, tris[2-(4-chloro-phenyl)-propyl]aluminium, tris[2-(3-isopropyl-phenyl)-propyl]aluminium, tris(2-phenyl-butyl)aluminium, tris(3-methyl-2-phenyl-butyl)aluminium, tris(2-phenyl-pentyl)aluminium, tris[2-(pentafluorophenyl)-propyl]aluminium, tris[2,2-diphenyl-ethyl]aluminium and tris[2-phenyl-2-methyl-propyl]aluminium, as well as the corresponding compounds wherein one of the hydrocarbyl groups is replaced with a hydrogen atom, and those wherein one or two of the hydrocarbyl groups are replaced with an isobutyl group.

Amongst the above aluminium compounds, trimethylaluminium (TMA), triisobutylaluminium (TIBA), tris(2,4,4-trimethyl-pentyl)aluminium (TIOA), tris(2,3-dimethylbutyl)aluminium (TDMBA) and tris(2,3,3-trimethylbutyl)aluminium (TTMBA) are preferred.

Non-limiting examples of compounds able to form an alkylmetallocene cation are compounds of formula  $D^+E^-$ , wherein  $D^+$  is a Brønsted acid, able to donate a proton and to react irreversibly with a substituent X of the metallocene of formula (I) and  $E^-$  is a compatible anion, which is able to stabilize the active catalytic species originating from the reaction of the two compounds, and which is sufficiently labile to be removed by an olefinic monomer. Preferably, the anion  $E^-$  comprises one or more boron atoms. More preferably, the anion  $E^-$  is an anion of the formula  $BAr_4^{(-)}$ , wherein the substituents Ar which can be identical or different are aryl radicals such as phenyl, pentafluorophenyl or bis(trifluoromethyl)phenyl. Tetrakis-pentafluorophenyl borate is particularly preferred compound, as described in WO 91/02012. Moreover, compounds of formula  $BAr_3$  can be conveniently used. Compounds of this type are described, for example, in the International patent application WO 92/00333. Other examples of compounds able to form an alkylmetallocene cation are compounds of formula  $BAr_3P$  wherein P is a substituted or unsubstituted pyrrol radical. These compounds are described in WO01/62764. Compounds containing boron atoms can be conveniently supported according to the description of DE-A-19962814 and DE-A-19962910. All these

compounds containing boron atoms can be used in a molar ratio between boron and the metal of the metallocene comprised between about 1:1 and about 10:1; preferably 1:1 and 2.1; more preferably about 1:1.

Non limiting examples of compounds of formula  $D^+E^-$  are:

Triethylammoniumtetra(phenyl)borate,  
Tributylammoniumtetra(phenyl)borate,  
Trimethylammoniumtetra(tolyl)borate,  
Tributylammoniumtetra(tolyl)borate,  
Tributylammoniumtetra(pentafluorophenyl)borate,  
Tributylammoniumtetra(pentafluorophenyl)aluminate,  
Tripropylammoniumtetra(dimethylphenyl)borate,  
Tributylammoniumtetra(trifluoromethylphenyl)borate,  
Tributylammoniumtetra(4-fluorophenyl)borate,  
N,N-Dimethylbenzylammonium-tetrakis(pentafluorophenyl)borate,  
N,N-Dimethylhexylammonium-tetrakis(pentafluorophenyl)borate,  
N,N-Dimethylaniliniumtetra(phenyl)borate,  
N,N-Diethylaniliniumtetra(phenyl)borate,  
N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate,  
N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)aluminate,  
N,N-Dimethylbenzylammonium-tetrakis(pentafluorophenyl)borate,  
N,N-Dimethylhexylammonium-tetrakis(pentafluorophenyl)borate,  
Di(propyl)ammoniumtetrakis(pentafluorophenyl)borate,  
Di(cyclohexyl)ammoniumtetrakis(pentafluorophenyl)borate,  
Triphenylphosphoniumtetrakis(phenyl)borate,  
Triethylphosphoniumtetrakis(phenyl)borate,  
Diphenylphosphoniumtetrakis(phenyl)borate,  
Tri(methylphenyl)phosphoniumtetrakis(phenyl)borate,  
Tri(dimethylphenyl)phosphoniumtetrakis(phenyl)borate,  
Triphenylcarbeniumtetrakis(pentafluorophenyl)borate,  
Triphenylcarbeniumtetrakis(pentafluorophenyl)aluminate,  
Triphenylcarbeniumtetrakis(phenyl)aluminate,  
Ferroceniumtetrakis(pentafluorophenyl)borate,  
Ferroceniumtetrakis(pentafluorophenyl)aluminate.

Triphenylcarbeniumtetrakis(pentafluorophenyl)borate, and  
N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate.

Organic aluminum compounds used as compound iii) are those of formula  $H_jAlU_{3-j}$  or  $H_jAl_2U_{6-j}$  as described above.

The polymerization process of the present invention can be carried out in liquid phase, optionally in the presence of an inert hydrocarbon solvent. Said hydrocarbon solvent can be either aromatic (such as toluene) or aliphatic (such as propane, hexane, heptane, isobutane, cyclohexane and 2,2,4-trimethylpentane). Preferably, the polymerization process of the present invention is carried out by using the alpha olefin of formula  $CH_2=CHW$  wherein W is a  $C_3$ - $C_{10}$  hydrocarbon radical such as 1-hexene or 1-octene as polymerization medium, i.e. the same olefin that is going to be polymerized for example 1-hexene is used as polymerization medium when a 1-hexene based polymer is the wished polymer.

The polymerization temperature preferably ranges from 0°C to 250°C; preferably comprised between 20°C and 150°C and, more particularly between 40°C and 90°C;

The molecular weight distribution can be varied by using mixtures of different metallocene compounds or by carrying out the polymerization in several stages which differ as to the polymerization temperature and/or the concentrations of the molecular weight regulators and/or the monomers concentration. Moreover by carrying out the polymerization process by using a combination of two different metallocene compounds of formula (I) a polymer endowed with a broad melting is produced.

With the process of the present invention isotactic polymers endowed with high molecular weights can be obtained in high yields.

With the process of the present invention polymers containing derived units of one or more alpha olefins of formula  $CH_2=CHW$  wherein W is a  $C_3$ - $C_{10}$  hydrocarbon radical and optionally from 0 to 81% by mol of derived units of propylene or 1-butene can be obtained. Examples of alpha olefins of formula  $CH_2=CHW$  are 1-pentene; 1-hexene; 1-octene and 1-decene. Preferably 1-hexene and 1-octene are used; more preferably 1-hexene is used.

When said alpha olefins of formula  $CH_2=CHW$  are copolymerized with propylene or 1-butene preferably the obtained copolymer has a content of derived units of propylene or 1-butene ranging from 0.1% by mol to 59% by mol; more preferably the content of propylene or 1-butene ranges from 10% by mol to 50% by mol, even more preferably it ranges from 19% by mol to 40% by mol.

The obtained copolymer is endowed with the following properties:

- i) intrinsic viscosity IV measured in tetrahydronaphtalene (THN) at 135°C higher than 0.90 dl/g; preferably higher than 1.20 dl/g; more preferably higher than 1.30 dl/g; even more preferably higher than 1.80 dl/g;
- ii) distribution of molecular weight  $M_w/M_n$  lower than 3; preferably lower than 2.5; and
- iii) no enthalpy of fusion detectable at a differential scanning calorimeter (DSC) wherein the DSC measurement is carried out as described below.

In said copolymer the alpha olefin of formula  $\text{CH}_2=\text{CHW}$  is preferably 1-hexene and 1-octene.

The copolymers, other than the above properties, are further endowed with a very low Shore A (measured according to ISO 868), in particular the shore A is lower than 30; preferably lower than 25; more preferably lower than 20; and furthermore the tensile modulus is lower than 20 MPa (measured according to ASTM 5026,4092 e 4065); preferably lower than 15MPa; more preferably lower than 11 MPa.

A further preferred range of content of derived units of propylene and 1-butene is from 19% by mol to 59% by mol; even more preferably from 30% by mol to 59% by mol.

The process of the present invention is particularly suitable for preparing homopolymers of alpha olefins of formula  $\text{CH}_2=\text{CHW}$  wherein W is a  $\text{C}_3\text{-C}_{10}$  hydrocarbon radical, in particular homopolymers of 1-hexene or 1-octene; preferably homopolymer of 1-hexene are produced.

The homopolymer prepared according to the present invention can be used for application known in the art such as masterbatches or in adhesive formulations.

Even if the homopolymer of the present invention are not exemplified, their preparation can be easily achieved by the skilled man once it is know the process for preparing the copolymers. In fact it is sufficient to avoid to add the comonomer in the processes exemplified above for obtaining the wished homopolymer.

The copolymers obtainable with the process of the present invention described above, can have the same uses of the homopolymer and furthermore they can be used as compatibilizer. For example they can improve the dispersion of a rubber phase in an crystalline matrix, due to the presence of the comonomer that help to compatibilize the two phases, so that a material having an improved izod impact value can be obtained.

The following examples are given to illustrate and not to limit the invention.

## EXAMPLES

### GENERAL PROCEDURES AND CHARACTERIZATIONS

All chemicals were handled under nitrogen using standard Schlenk techniques.

Methylalumoxane (MAO) was received from Albemarle as a 30% wt/vol toluene solution and used as such.

Pure triisobutylaluminum (TIBA) was used as such.

Isododecane was purified over aluminum oxide to reach a water content below 10 ppm.

A 101 g/L TIBA/isododecane solution was obtained by mixing the above components.

The melting points of the polymers ( $T_m$ ) were measured by Differential Scanning Calorimetry (D.S.C.) on a Perkin Elmer DSC-7 instrument, according to the standard method. A weighted sample (5-7 mg) obtained from the polymerization was sealed into aluminum pans and heated to 180°C at 10°C/minute. The sample was kept at 180°C for 5 minutes to allow a complete melting of all the crystallites, then cooled to 20°C at 10°C/minute. After standing 2 minutes at 20°C, the sample was heated for the second time to 180°C at 10°C/min. In this second heating run, the peak temperature was taken as the melting temperature ( $T_m$ ) and the area of the peak as melting enthalpy ( $\Delta H_f$ ).

Molecular weight parameters were measured using a Waters 150C ALC/GPC instrument (Waters, Milford, Massachusetts, USA) equipped with four mixed-gel columns PLgel 20  $\mu$ m Mixed-A LS (Polymer Laboratories, Church Stretton, United Kingdom). The dimensions of the columns were 300  $\times$  7.8 mm. The solvent used was TCB and the flow rate was kept at 1.0 mL/min. Solution concentrations were 0.1 g/dL in 1,2,4 trichlorobenzene (TCB). 0.1 g/L of 2,6-di-*t*-butyl-4-methyl phenol (BHT) was added to prevent degradation and the injection volume was 300  $\mu$ L. All the measurements were carried out at 135°C. GPC calibration is complex, as no well-characterized narrow molecular weight distribution standard reference materials are available for 1-hexene polymers. Thus, a universal calibration curve was obtained using 12 polystyrene standard samples with molecular weights ranging from 580 to 13,200,000. It was assumed that the  $K$  values of the Mark-Houwink relationship were:  $K_{PS} = 1.21 \times 10^{-4}$ , dL/g and  $K_{PH} = 1.78 \times 10^{-4}$  dL/g for polystyrene and poly-1-hexene respectively, for the copolymers the same  $K_{PH}$  has been used. The Mark-Houwink exponents  $\alpha$  were assumed to be 0.706 for polystyrene and 0.725 for poly-1-hexene and copolymers. Even though, in this approach, the molecular parameters obtained were only an estimate of the hydrodynamic volume of each chain, they allowed a relative comparison to be made.

The intrinsic viscosity (I.V.) was measured in tetrahydronaphthalene (THN) at 135°C.

rac dimethylsilandiylbis-6-[2,5-dimethyl-3-(2'-methyl-phenyl)cyclopentadienyl-[1,2-b]-thiophene]zirconium dichloride (A-1) was prepared according to WO01/44318.

### Preparation of catalyst systems

#### Preparation of catalyst system C-1 A-1/MAO:TIBA 2:1 (400)

9.8cc of TIBA/isododecane solution (101g/L) were mixed with 1.91 cc of MAO/ toluene solution (Albemarle -30%wt) to obtain a MAO/TIBA molar ratio of 2:1. The solution was stirred for 1 hour at room temperature. Then, 26 mg of A-1 were dissolved in the solution.

The orange solution did not show any trace of residual solid .

The final solution was diluted with 4 cc of isododecane to reach a concentration of 100g/L.

### Polymerization tests

#### 1-hexene copolymerisation

An amount of purified liquid 1-hexene as indicated in table 1 was transferred reactor at room temperature in a 250 glass vessel under nitrogen atmosphere. The reactor had been maintained under slight positive nitrogen atmosphere at all time. Consequently the temperature was increased to the polymerization temperature indicated in table 2 and an over pressure of 1 bar-g of propylene or 1-butene was fed in the autoclave. The catalyst solution, (ageing indicated in table 2), was fed into the liquid, under a nitrogen flow. The pressure was increased adding propylene until reaching the polymerisation pressure indicated in table 2. The polymerization was conducted for 60 minutes, then stopped by flashing the monomers. The polymer was precipitated by adding acetone to the polymer solution. The recovered polymer was dried at 50°C under vacuum. Polymerization and polymer data are reported in table 1.

Table 1

Ex	Cat (mg. of A-1)	1-hexene g	Monomer (bar-g)	Pol. Temp. °C	Ageing hours	Activity Kg/g met/h
1	C-1 (1.3)	54	propylene (3)	50	48	20
2	C-1 (1)	54	propylene (6)	50	144	12
3	C-1 (1.64)	54	1-butene (2)	70	216	27
4	C-1 (1.64)	54	1-butene (2)	50	24	22

Table 1 continued

Ex	1-hexene mol%	Mw	Mw/Mn	IV (THN) dl/g	$\Delta H$
1	79.1	223700	1.9	1.21	n.d.
2	63.7	286500	2.1	1.6	n.d.
3	75.4	n.a.	n.a.	n.a.	n.d.
4	62.3	n.a.	n.a.	n.a.	n.d.

n.a. not available

n.d. not detectable.

### 1-hexene/propylene copolymerisation

4 mmol of  $\text{Al}(i\text{-Bu})_3$  (as a 1M solution in hexane) and 1000g of 1-hexene were charged at room temperature in a 4-L jacketed stainless-steel autoclave, previously purified by washing with an  $\text{Al}(i\text{-Bu})_3$  solution in hexane and dried at 50°C in a stream of nitrogen. The autoclave was then thermostated at the polymerisation temperature, 70°C, and then the solution containing the catalyst/cocatalyst solution indicated in table 3 prepared 12 hours before was injected in the autoclave by means of nitrogen pressure through the stainless-steel vial. The monomer was fed until a pressure indicated in table 3 and the polymerisation carried out at constant temperature for 1 hour. The pressure into the autoclave is decreased until 20 bar-g and the polymerization solution is discharged into a heated steel tank containing water at 70°C. The tank heating is switched off and a flow of nitrogen at 0.5 bar-g is fed. After cooling at room temperature, the steel tank is opened and the wet polymer collected and dried at 70°C under reduced pressure. The polymerisation conditions and the characterisation data of the obtained polymers are reported in Table 2.

table 2

Ex	Cat (mg. of met)	Monomer bar-g	Activity Kg/g met/ h	1-hexene mol%	Mw	Mw/Mn	IV (THN) dl/g	$\Delta H$
5	C-1 (6.56)	propylene (19)	53	26	184500	2	1.2	n.a.
6	C-1 (6.56)	propylene (13)	23	42	172100	2	1.0	n.d.
7	C-1 (6.56)	1-butene (5)	24	43	177700	2	1.0	n.d.

n.a. not available

n.d. not detectable.

The shore A (ISO 868) of copolymers of examples 6 and 7 has been measured, the results are reported in table 3. The tensile modulus of a sample of copolymers obtained in examples 6 and 7 has been measured according to ASTM 5026,4092 and 4065 as follows:

Specimens for tensile test are cut from compression moulding plaques. Specimen sizes are approx. 40 mm long overall, 20 mm inter-clamp length, 6 mm width and thickness was 1 mm. Specimen is clamped in the SEIKO DMS 6100 tensile DMTA.

The applied frequency is 1 Hz.

Specimens are heated from -80°C to +140°C with 2°C/min as heating rate; specimens are re-clamped at the low temperature.

The results are reported in table 3

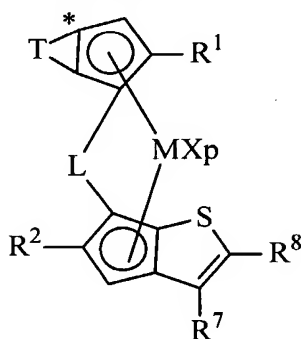
Table 3

Ex	shore A	tensile modulus (MPa)
6	5	<10
7	4	<10



## Claims

1. A process for preparing a polymer containing derived units of one or more alpha olefins of formula  $\text{CH}_2=\text{CHW}$  wherein W is a  $\text{C}_3\text{-C}_{10}$  hydrocarbon radical and optionally from 0 to 81% by mol of derived units of propylene or 1-butene, comprising contacting under polymerization conditions one or more alpha olefins of formula  $\text{CH}_2=\text{CHW}$  and optionally propylene or 1-butene in the presence of a catalyst system obtainable by contacting:
  - a) a metallocene compound of formula (I)



(I)

wherein

M is an atom of a transition metal selected from those belonging to group 3, 4, 5, 6 or to the lanthanide or actinide groups in the Periodic Table of the Elements;

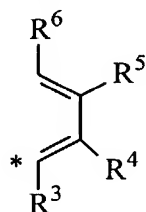
p is an integer from 0 to 3, being equal to the formal oxidation state of the metal M minus 2;

X, same or different, is a hydrogen atom, a halogen atom, or a R, OR,  $\text{OSO}_2\text{CF}_3$ , OCOR, SR,  $\text{NR}_2$  or  $\text{PR}_2$  group, wherein R is a are linear or branched, cyclic or acyclic,  $\text{C}_1\text{-C}_{40}$ -alkyl,  $\text{C}_2\text{-C}_{40}$  alkenyl,  $\text{C}_2\text{-C}_{40}$  alkynyl,  $\text{C}_6\text{-C}_{40}$ -aryl,  $\text{C}_7\text{-C}_{40}$ -alkylaryl or  $\text{C}_7\text{-C}_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; or two X can optionally form a substituted or unsubstituted butadienyl radical or a  $\text{OR}'\text{O}$  group wherein  $\text{R}'$  is a divalent radical selected from  $\text{C}_1\text{-C}_{40}$  alkylidene,  $\text{C}_6\text{-C}_{40}$  arylidene,  $\text{C}_7\text{-C}_{40}$  alkylarylidene and  $\text{C}_7\text{-C}_{40}$  arylalkylidene radicals;

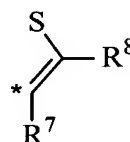
L is a divalent C<sub>1</sub>-C<sub>40</sub> hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements or a divalent silylene radical containing up to 5 silicon atom;

R<sup>1</sup> and R<sup>2</sup>, equal to or different from each other, are C<sub>1</sub>-C<sub>40</sub> hydrocarbon radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

T, equal to or different from each other, is a moiety of formula (IIa) or (IIb):



(IIa)



(IIb)

wherein the atom marked with the symbol \* bonds the atom marked with the same symbol in the compound of formula (I);

R<sup>3</sup> is a hydrogen atom or a C<sub>1</sub>-C<sub>40</sub> hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R<sup>4</sup> and R<sup>6</sup>, equal to or different from each other, are hydrogen atoms or C<sub>1</sub>-C<sub>40</sub> hydrocarbon radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R<sup>5</sup> is a hydrogen atom or a C<sub>1</sub>-C<sub>40</sub> hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

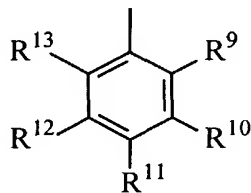
R<sup>7</sup> and R<sup>8</sup>, equal to or different from each other, are hydrogen atoms or C<sub>1</sub>-C<sub>40</sub> hydrocarbon radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R<sup>7</sup> and R<sup>8</sup> can optionally form a saturated or unsaturated, 5 or 6 membered rings, said ring can bear C<sub>1</sub>-C<sub>20</sub> alkyl radicals as substituents; and

(b) an alumoxane or a compound capable of forming an alkyl metallocene cation;

2. The process according to claim 1 wherein the catalyst system further contains c) an organo aluminum compound.
3. The process according to claims 1 or 2 wherein in the compound of formula (I) M is titanium, zirconium or hafnium; X is a hydrogen atom, a halogen atom or a R

group, wherein R has been defined as in claim 1; and L is a divalent bridging group selected from C<sub>1</sub>-C<sub>40</sub> alkylidene, C<sub>3</sub>-C<sub>40</sub> cycloalkylidene, C<sub>6</sub>-C<sub>40</sub> arylidene, C<sub>7</sub>-C<sub>40</sub> alkylarylidene, or C<sub>7</sub>-C<sub>40</sub> arylalkylidene radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements, and silylene radical containing up to 5 silicon atoms.

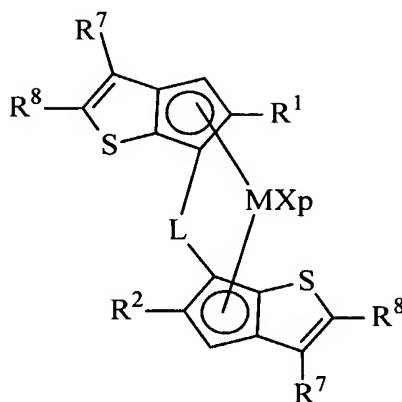
4. The process according to anyone of claims 1-3 wherein in the compound of formula (I) L is a group (Z(R'')<sub>2</sub>)<sub>n</sub> wherein Z is a carbon or a silicon atom, n is 1 or 2 and R'' is a C<sub>1</sub>-C<sub>20</sub> hydrocarbon radical optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements.
5. The process according to anyone of claims 1-4 wherein R<sup>1</sup> and R<sup>2</sup> are linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl radicals; R<sup>3</sup> is a linear or branched, C<sub>1</sub>-C<sub>20</sub>-alkyl C<sub>6</sub>-C<sub>40</sub>-aryl, C<sub>7</sub>-C<sub>40</sub>-arylalkyl radical; R<sup>4</sup> and R<sup>6</sup> are hydrogen atoms; R<sup>5</sup> is a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl radical; R<sup>8</sup> is a hydrogen atom or a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl radical; and R<sup>7</sup> is a C<sub>1</sub>-C<sub>40</sub>-alkyl, C<sub>6</sub>-C<sub>40</sub>-aryl or a C<sub>7</sub>-C<sub>40</sub>-arylalkyl radical.
6. The process according to claim 5 wherein R<sup>7</sup> is a group of formula (III)



(III)

wherein R<sup>9</sup>, R<sup>10</sup>, R<sup>11</sup>, R<sup>12</sup> and R<sup>13</sup>, equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic, C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>2</sub>-C<sub>20</sub> alkenyl, C<sub>2</sub>-C<sub>20</sub> alkynyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements.

7. The process according to anyone of claims 1-6 wherein the metallocene compound has formula (IV):

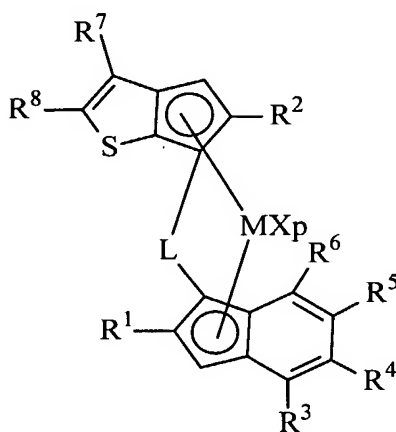


(IV)

wherein

M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup> and R<sup>6</sup> have the meaning described in claim 1.

8. The process according to anyone of claims 1-6 wherein the metallocene compound in its meso or meso-like form has formula (V):



(V)

wherein M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup> and R<sup>8</sup> have the meaning described in claim 1.

9. The process according to anyone of claims 1-7 wherein the polymerization process is carried out by using 1-hexene as polymerization medium.
10. The process according to anyone of claims 1-8 wherein 1-hexene is homopolymerized.
11. The process according to anyone of claims 1-8 wherein 1-hexene is copolymerized with propylene or 1-butene.

12. A copolymer comprising from 41% by mol to 99.9% by mol of derived units of alpha olefins of formula  $\text{CH}_2=\text{CHW}$  wherein W is a  $\text{C}_3\text{-C}_{10}$  hydrocarbon radical and from 0.1 to 59% by mol of derived units of propylene or 1-butene endowed with the following properties:
  - i) intrinsic viscosity IV measured tetrahydronaphtalene (THN) at  $135^\circ\text{C}$  higher than 0.9 dl/g;
  - ii) distribution of molecular weight  $M_w/M_n$  lower than 3; preferably lower than 2.5; and
  - iii) no enthalpy of fusion detectable at a differential scanning calorimeter (DSC).
13. A copolymer according to claim 11 endowed with a shore A lower than 30 and a tensile modulus lower than 20 MPa.
14. A blend comprising the copolymer of claims 11 or 12.
15. Use of the copolymer of claims 11 and 12 as compatibilizer in an heterophasic blend comprising a crystalline matrix and a rubber phase.

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/EP2005/002480

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 C08F210/14

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 C08F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, CHEM ABS Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

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## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/EP2005/002480

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